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Performance Analysis of Data Transmission over Hybrid Free Space Optics Channel Using Soliton

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***Abstract* - Optical Communication system is widely used since they could process data at higher speeds meanwhile increasing the capacity of the network. Providing a secure transmission of data has been a greatest challenge over years. This paper demonstrates methods that mitigates the Nonlinear and dispersion effect in optical networks by evaluating the performance of high-capacity data transfer over hybrid FSO (Free Space Optic) channel using soliton pulses. The network performances are characterized based on clear, haze rain and fog conditions and their electro-optical properties are analysed. The data capacity of 0.5Tbps is generated and is made to transmit from the source to the receiver. The proposed FSO structure was able to achieve distance of >92km, >22km, >17.6 km for clear, heavy fog and light haze conditions respectively. The Bit Error Rate [BER] is found to be in the range of [10^-8 to 10^12] for all atmospheric turbulence conditions. These channels can be used in multi diversity-based environments and could be tested on turbulence conditions.**

***Index Terms* - Free Space Optics, BER, Atmospheric Condition, Hybrid FSO.**

INTRODUCTION

Communication is the transmission of information from one place to another through a medium. Mankind has been using many mediums for the data transmission. One of these mediums that really had a big impact on data transmission was coaxial cable system.

The first coaxial cable system, deployed in 1940 [2], was a 3MHz system which could transmit 300 voice channels. But these coaxial cables mostly suffer from high cable losses, repeater spacing is also very limited and is costly for a longer transmission length. And these shortcomings led to the development of microwave communication system.

Microwave communication system uses electromagnetic carrier waves in the range of GHz to transmit signals using different techniques to modulate the carrier waves. The microwave communication system allowed larger repeater spacing but suffered from limited bit rate. Then Optical fiber was first developed in the 1970s, which revolutionized the telecommunications industry and played a major role in the Information era. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in the developed world.

In spite of all the benefits utilizing FSO communication systems, atmospheric loss effect is considered as the main issue while designing communication systems. This atmospheric loss can be divided into two categories: atmospheric turbulence and atmospheric attenuation. The atmospheric turbulence cause deviation on the propagating optical radiation due to its dependency on the scattering, weather conditions etc.

In the existing systems, typical WDM rectangular pulses were used for the transmission And DPSK and QPSK modulation schemes were employed. This has witnessed an exponential rise in the demand for data traffic owing to huge increment in terms of high-speed internet, social networking, live streaming applications, high-definition video streaming, cloud computing, video conferencing, cable TV, etc. According to Cisco reports, by the year 2021, the demand for data traffic will be greater than 49 Exabyte, which is seven times more than the current demand. This rising demand for data traffic can be effectively fulfilled by optical fiber technology which has the potential to provide Terabit transmission links.

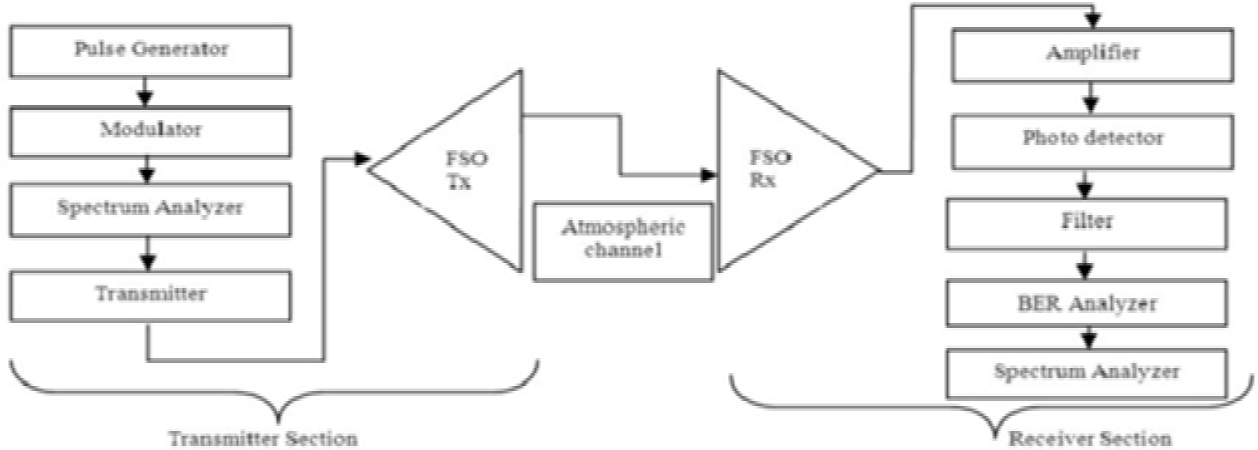


Fig1: Block Diagram of FWM communication

Free Space Optics (FSO) technology is another emerging data transmission technique which has the same underlying principle as the optical fiber systems. FSO links capitalize on optically modulated data transmission over free space/atmosphere as the transmission medium with no requirement of installation of optical fiber cables. FSO links have the potential to offer similar merits including high-speed data transmission, large bandwidth for the end users, unlicensed frequency spectrum, easy and quick installation and relocation, secure links with low security upgrades, immunity to Radio Frequency (RF) and electromagnetic interference, etc. Further, FSO links provide an effective and viable solution to the problem of last mile access in rural areas, where the installation of optical fiber cables is impractical due to rough terrains and in urban areas where the cost of licensing is extremely high .The main factors which degrade the performance of FSO links are external environmental conditions such as rain, haze, fog, snow, etc. which absorb and scatter the information carrying photons resulting in a degradation in the signal quality at the receiver terminal which limits the maximum reach of the link. The results of the simulative analysis of this link exhibited successful transportation of 80 Gbps data over free space channel under the influence of dynamic environmental conditions. The modeling and bit-error rate (BER) investigation of Spectrum Sliced WDM (SS-WDM) based 4-channel FSO link under varying environmental conditions of Vellore has been reported in [10]. The paper demonstrated successful transportation of 4k 1:56 Gbps data using the proposed link. The paper[3] reported the development of high-speed FSO link with 4-channel WDM architecture incorporating Polarization Shift Keying (PolSK) modulation technique for enhanced performance . The results demonstrated a reliable transmission of 4k 10 Gbps data under the influence of different weather conditions. FSO system should have the ability to operate over wide temperature range and the performance degradation would be less for outdoor systems. Mean Time Between Failures (MTBF) of system should be more than 10 years. The Free Space Optics is a flexible network that delivers better speed than broadband. Installation is very easy, and it takes less than 30 minutes to install at normal locations. It has very low initial investment and has straight forward deployment system. Thus Free Space Optics provides numerous advantages over the existing system. But as the medium of the transmission is air for FSO and the light passes through it, some environmental challenges are unavoidable. Troposphere regions are the region where most of the atmospheric phenomenon occurred. These temperature variations can cause fluctuations in amplitude of the signal which causes “image dancing” at the FSO receiving end.

Table:1 Attenuation constants for different environmental conditions

	Haze	RRain	Fog
Light	1.527dB/km	6.27dB/km	9dB/km
Medium	4.285dB/km	9.64dB/km	16dB/km
Heavy	10.115dB/km	19.28dB/km	22dB/km

II. PROPOSED FWM CHANNEL USING HYBRID FSO LINK ARCHITECTURE

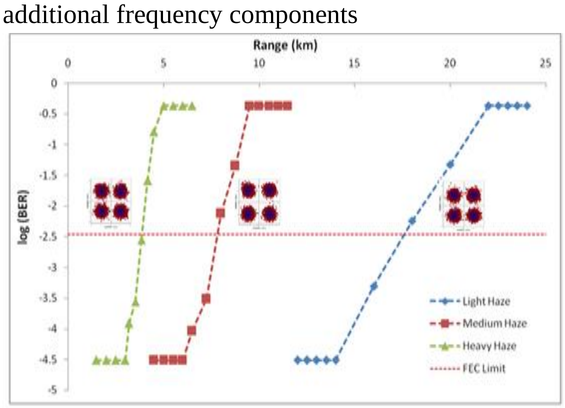
The proposed FSO link incorporates FWM super channel transmission. The proposed link is modeled and analysed using optisystem software. The Transmitter consists of continuous wave laser kept at optimal frequency spacing, multiplexed and passed to a travelling wave Semiconductor Optical Amplifier (SOA) to generate the nonlinear effect. The nonlinearity due to the frequency spacing at the source creates an additional number of frequency bands which is due to the property of FWM (Four Wave Mixing). These resultant bands are amplified with the help of erbium doped amplifier and passed to the bessel optical filter which is kept at a desired frequency range that allows only particular spectrum and rejects other spectral components This optical spectral signal is given as the carrier signal to the Mach Zehnder modulator as one of the input and pseudo randomly generated pulse electrical signal is given as another input to the Mach Zehnder modulator. The modulator produces the modulated output. There are several number of transmitter setups with the same structure having different sources with different wavelength being multiplexed to produce combined output. When a high-power optical signal is launched into a fiber, the linearity of the optical response is lost. One such nonlinear effect, which is due to the third order electric susceptibility is called the optical Kerr effect. Four-wave mixing (FWM) is a type of optical Kerr effect and it occurs when light of two or more different wavelengths is launched into a fiber. Generally speaking, FWM occurs when light of three different wavelengths is launched into a fiber giving rise to a new wave known as an idler, the wavelength of which does not coincide with any of other wavelengths. FWM is a kind of optical parametric oscillation. In the transmission of dense wavelength-division multiplexed (DWDM) signals, FWM is to be avoided, but for certain applications, it provides an effective technological basis for fiber-optic devices. FWM also provides the basic technology for measuring the nonlinearity and chromatic dispersion of optical fibers. This paper discusses those aspects of research into FWM applications related to simultaneous wavelength conversion and the technique for measuring nonlinear coefficient of optical fibers. The Four-Wave Mixing is performed in frequency domain. As it can be seen, the light that was there from before launching, sandwiching the two pumping waves in the frequency domain, is called the probe light or signal light. The idler frequency fidler may then be determined by

$$f_{idler} = 2f_p - f_{probe}$$

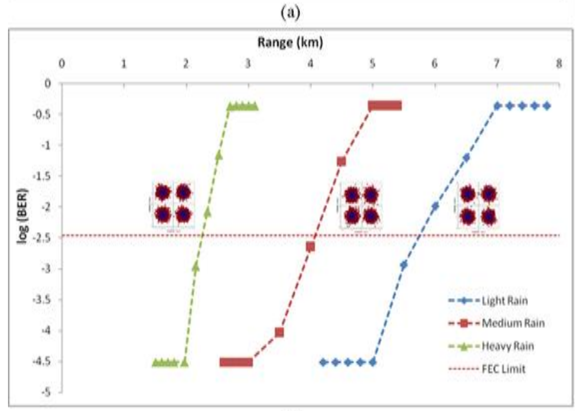
This condition is called the frequency phase-matching condition. When the frequencies of the two pumping waves are identical, the more specific term "Degenerated Four-Wave Mixing" (DFWM) is used and the equation for this case may be written.

$$f_{idler} = f_{p1} + f_{p2} - f_{probe}$$

where fp is the frequency of the degenerated pumping wave. Four-Wave Mixing is a non-linear effect arising from a third-order optical nonlinearity, as is described with x 3 coefficient. It can occur if at least two different frequency components propagate together in a nonlinear medium such as an optical fiber. Assuming just two input frequency components V1 and V2 (with V2 > V1), a refractive index modulation at the difference frequency occurs, which creates two additional frequency components



(a)



(b)

Fig: 2 log (BER) versus transmission range under varying levels of (a) haze weather (b) rain weather

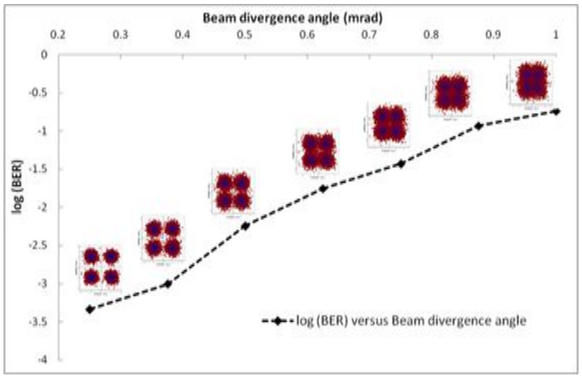


Fig:3 log (BER) verus beam divergence angle

III. RESULTS AND DISCUSSION

This section reports the transmission performance analysis of the proposed 6.4 Tbps FSO link incorporating FWM super channel transmission. The plots of log (BER) versus FSO transmission range under clear weather conditions using the proposed FWM super channel transmission link is illustrated. The results show that the BER of the received signal increases as the transmission range in the proposed link increases. Also, it can be seen that with the increase in the transmission range of the proposed link, the constellation plots of the received signal get more distorted which makes it difficult for the receiver unit to reliably retrieve the information. The degradation in the quality of the received signal can be attributed to the fact that as the transmission range increases, the optical information signal power loss also increases due to atmospheric attenuation. The maximum supported transmission range with faithful log (BER) (2.42)i.e. Forward Error Correction (FEC) limit under clear weather using the proposed 6.4 Tbps FWM super channel FSO transmission link is 92 km with a spectral efficiency of 3.33 bits/s/Hz

Fig. 3 reports log (BER) versus the beam divergence angle at 70 km transmission range using the proposed link. The results show that the BER and the distortion in the constellation plots of the received signal increases with increasing beam divergence. The increasing distortion of the received signal with increasing beam divergence angle makes it difficult for the demodulator unit to reliably intercept the information signal transmitted. The log (BER) increases from 3.33 at 0.25 mrad divergence angle to 0.74 at 1 mrad divergence angle using the proposed link. Further, the performance of the proposed link under the influence of dynamic weather conditions are reported in Fig. 2 From Fig. 2, it can be observed that BER of the received signal increases as the atmospheric attenuation coefficient value increases for different weather conditions. The maximum supported transmission range with fair BER is 17.6 km under light haze, 7.9 km under medium haze, and 3.9 km under heavy haze. Similarly, the maximum transmission range under light rain is 5.75 km, under medium rain is 4.1 km, and 2.25 km under heavy rain. Also the maximum transmission range is 4.3 km under light fog, 2.65 km under medium fog and 2 km under heavy fog conditions

IV. CONCLUSION

In this paper, the modeling of a novel 6.4 Tbps FSO link incorporating FWM super channel transmission with Mach Zender modulated signals was presented. The performance of the proposed link has been numerically investigated over different environmental effects through numerical simulation. The obtained results reveal that the maximum supported transmission range using the proposed link varies from 2 km to 92 km depending on the weather conditions with a spectral efficiency of 3.33 bits/s/Hz. The impact of increasing beam divergence on the proposed FSO link performance has also been numerically investigated and the results demonstrate that the BER of the received signal increases as the beam divergence increases. The proposed link performance is compared with the existing methods and it is observed that the proposed method out performs the existing methods in terms of net information capacity and supports maximum transmission range. The proposed work can be used for the development of ultrahigh spectral efficient FSO link for 5G communication in the future.

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